SLID FIRE CONTROL SYSTEM
INTEGRATED SENSOR SUITE

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Abstract

Rockwell International Corporation has been developing a small, autonomous, active self defense system over the past four years under IR&D and government contract. One element of this system is a fully integrated fire control system that, in a small package, contains a full sensor suite for threat warning, tracking, and designation of threat missiles and projectiles

Introduction

Rockwell, under contract with the Defense Advanced Research Projects Agency (DARPA), is developing an integrated system for defending armored vehicles and high-value military assets against threats such as guided missiles, artillery projectiles, and mortar rounds. This system, designated SLID for Small, Low-cost Interceptor Device, consists of a Threat Warning System (TWS), a Fire Control System (FCS), one or more 4-barrel launchers, and a complement of hit-to-kill interceptors which destroy the threat missile or projectile with kinetic energy at impact. One application is the defense of Bradley Fighting Vehicles, and the artist's rendering shown as figure 1 illustrates the system in action defending a Bradley against a Soviet AT-6 missile. In the figure, the threat is being designated with a high pulse repetition frequency (prf) laser which is also performing ranging and autotrack functions. The rolling airframe interceptor, which is four inches in diameter and 21 inches long, uses a strapdown laser seeker to home on the threat via reflected laser energy, maneuvers by use of high impulse divert thrusters, and intercepts at standoff ranges of 100 to 300 meters. Axial propulsion is provided by a short-burn rocket motor which boosts the interceptor to a velocity of 260 meters/second.

The most stressing SLID system requirement is defense of a protected vehicle from a High Explosive Anti-Tank (HEAT) round fired from a range of one kilometer. The SLID TWS senses the muzzle flash at t=0 and takes 50 millisecond to extract the flash from the background, run it through the FCS processor, declare it as a potential threat, and hand over the global coordinates to the tracking system. The FCS tracking turret and optical pointing system take another 150 milliseconds to rotate to the defined coordinates, put the narrow field of view infrared tracking sensor's acquisition gate on the incoming round, process the image, lock the tracking gate down, and activate the co-boresighted laser. In another 50 milliseconds the FCS laser receiver and processor determine the threat kinematics in 3-dimensional space, define the optimum intercept point for 100 meter standoff at intercept, and pass those coordinates to the launcher. The launcher slews and settles in another 250 milliseconds while the thermal batteries on board the interceptor are activated. Tracking functions are then handed over from the narrow-field of view infrared tracker to the laser designator/autotracker system. The laser prf switches from 100 Hz to 750 Hz and the interceptor is launched through the frangible cover of the launch tube. Four hundred milliseconds later the HEAT round is struck in flight and destroyed. Total elapsed time is 9/10ths of a second from launch flash to intercept.

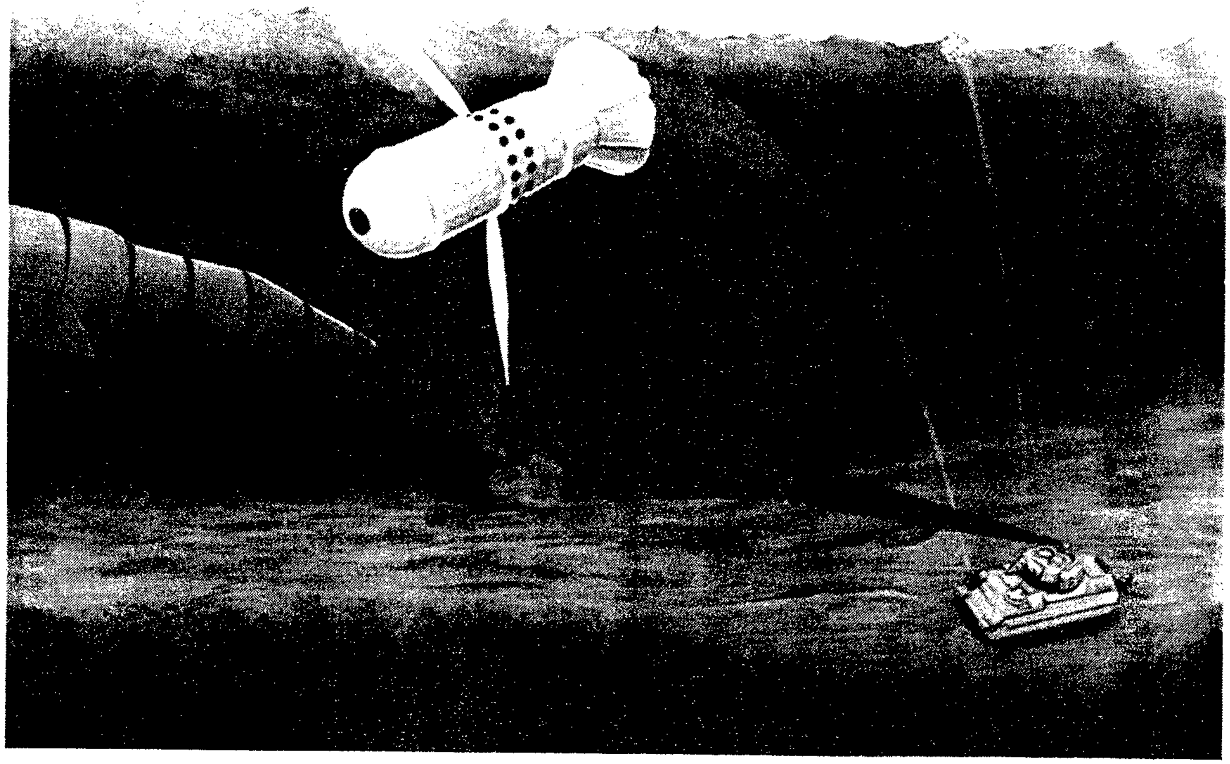

Figure 1. Rockwell SLID System Defending a M-2 Bradley Vehicle

SLID System Overview

The SLID active defense system consists of four major elements which are integrated to perform the SLID mission autonomously and efficiently. These are the TWS, the FCS, the high slew rate launcher, and the hit-to-kill interceptor. These systems are supported by an external power supply which converts and distributes 28VDC input power and contains capacitor banks for surge power requirements when the launcher is activated and responding to pointing commands. All system signal processing (except for interceptor guidance and control) is done with the FCS central processor, a C-80 based system which has adequate speed and throughput for all of the system's processing requirements. The subsystems that make up the major system elements are shown in table I, and a chronological summary describing the SLID operational concept is shown in figure 2.

Table I. SLID Subsystems

System	Subsystem	Description	Details
TWS	Threat Warning (see note 1)	WFOV MWIR Camera	640x480 MCT (4 ea.)
		or	
		WFOV LWIR Camera	640x480 MCT (4 ea.)
FCS	Fine Tracking	NFOV MWIR Camera (see note 2)	640x480 MCT (1 ea.) (see note 3)
	Rangefinding,	Laser/Laser Receiver	1.06 micron NdYag

Table I. SLID Subsystems (continued)

System	Subsystem	Description	Details
	Designating and Terminal Tracking		
	Processing	System Central Processor	C-80 based
Launcher	Precision Pointing System	DC Torquer motors	Direct Drive
Interceptor	Seeker	Strapdown Laser	128x128 InGaAs Detector
	Guidance	Solid Diverters	150 lbf x 5ms (72 ea.)
	Propulsion	Solid Rocket	3000 lbf x 80ms

Notes (1) MWIR threat warning subsystem for lower 30 degree coverage; LWIR threat warning subsystem for upper 60 degree coverage.
(2) WFOV=Wide Field of View; NFOV=Narrow Field of View MWIR=Mid Wave Infrared; LWIR=Long Wave Infrared
(3) MCT=Mercury Cadmium Telluride

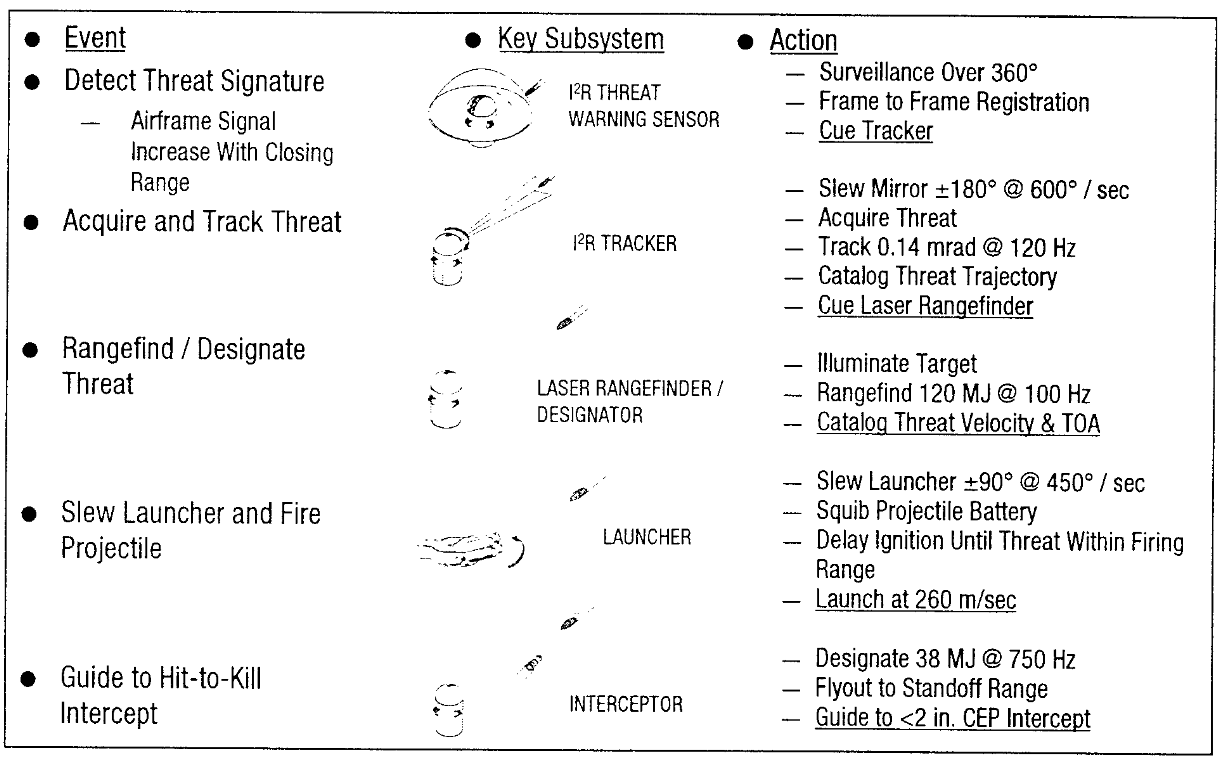

Figure 2. SLID Operational Concept

SLID Fire Control System Description

The TWS performs the threat detection function. It consists of either four WFOV MWIR sensors for line-of-sight threats such as HEAT rounds or anti-tank guided missiles, or four WFOV LWIR sensors for top-attack threats such as mortar and artillery rounds fired from deep defilade. Figure 3 shows the TWS sensors attached to the side of the FCS housing. In operation, the TWS detects the engagement event and then cues the tracker to the threat coordinates. These threat coordinates are input into the system processor threat table, and while the tracking optics are trained on the potential threat, the TWS continues to stare at the environment. Should another engagement event (e.g., launch flash) be sensed, the coordinates of that event would also be input into the threat table for interrogation a few milliseconds later. Fire control functions are then handed over to the tracker/designator subsystem.

Direct Fire TWS

- For Horizontal Attack Threats
- Lower 30° x 360° Coverage
- Four WFOV MWIR Sensors
- Excellent Performance Against Clutter Background

Top Attack TWS

- For Mortar and Artillery Threats
- Upper 60° X 360° Coverage
- Four WFOV LWIR Sensors
- Excellent Performance Against Cold Targets

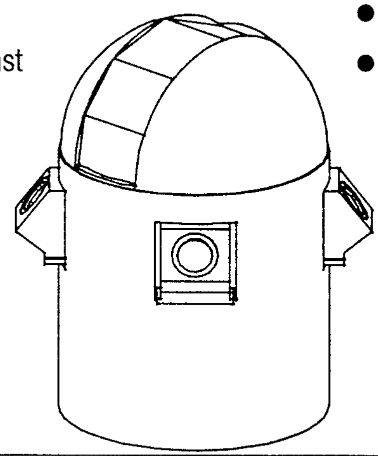

Figure 3. SLID Threat Warning Sensors

The tracker/designator subsystem uses a 3-degree field-of-view MWIR camera for fine tracking, and contains a co-boresighted 1.06 micron NdYag laser and laser receiver. The laser and laser receiver provide rangefinding, designating, and autotracking functions. Following handover from the TWS, the tracker/designator interrogates each of the candidate threats in the threat table to determine validity and priority. Non-threats are removed from the threat table, and priority threats are engaged before secondary (slower moving) threats. For threat interrogation the laser operates in the rangefinder mode with a prf of 100 Hz, an output energy of 120 millijoules, and a conical beamwidth of 1 milliradian. Beam steering is conducted with two stabilized steering mirrors in the optical dome as shown in figure 4, which is an exploded view of the tracker/designator subsystem elements. The dome features continuous 360 degree rotation for coarse tracker alignment, and all drive motors are sized for near instantaneous response.

Once the system commits to launch an interceptor, the laser is switched from rangefinding to the designation/autotrack mode of operation. The laser prf is increased to 750 Hz (required by the SLID interceptor for terminal accuracy), output energy drops to 38 millijoules (a consequence of the prf increase), and the beamwidth is increased to 4 milliradians to assure that the threat remains within the beam during autotrack. Prior to launch of the interceptor, the tracking functions are transferred from the IR tracking system to the laser receiver (required due to flash-blinding of the IR tracking sensor by the interceptor's rocket motor). Once autotrack is operating, the interceptor is launched, homes on the threat via reflected laser energy, and destroys it at the prescribed standoff distance.

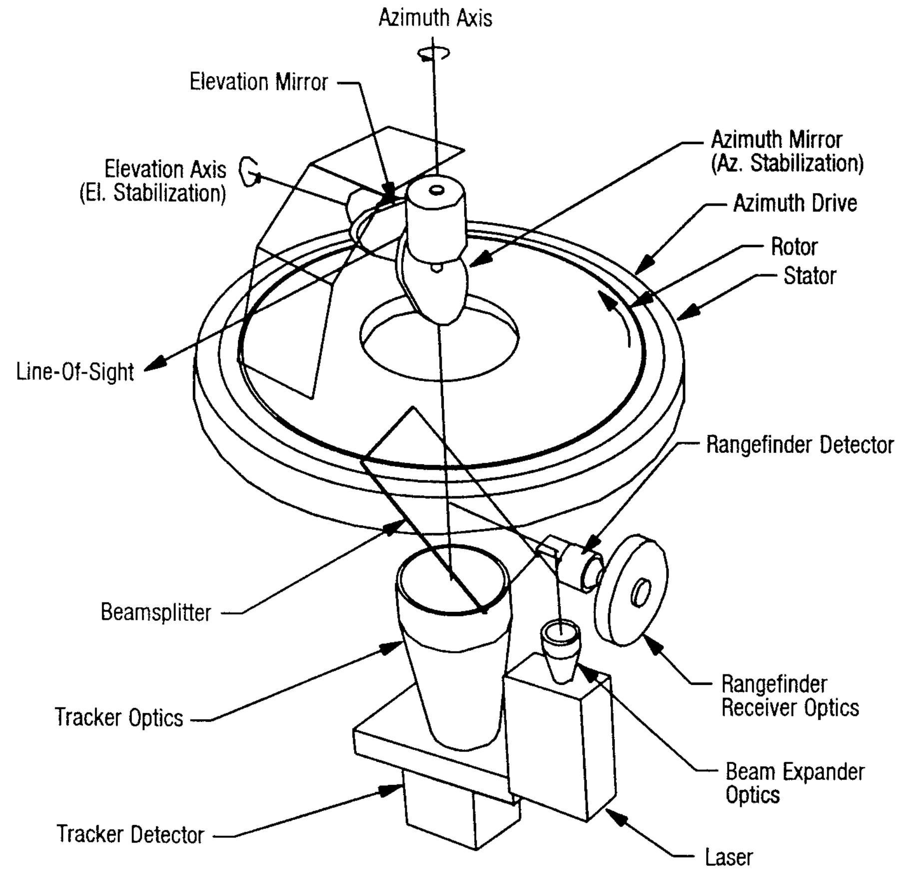

Figure 4. SLID FCS Tracker/Designator Subsystems

SLID FCS Performance

The FCS subsystems that perform the cueing, tracking, and designating functions have been selected based on studies and tests which have confirmed their performance in both good and inclement weather, and under the influence of dust, smoke, and other battlefield obscurants. These evaluations have demonstrated the robustness of the selected technologies for SLID application and have provided useful information for systems analyses of the performance timelines against a full range of surrogate threats, including HEAT, mortar, and artillery projectiles, and TOW, Dragon, and HELLFIRE missiles. Additionally, field testing has been conducted over the past two years to evaluate both wide and narrow field of view MWIR and LWIR sensor performance in clear, cloudy, hazy and overcast weather against Dragon and TOW missiles, and against HEAT and mortar projectiles. The laser designator and autotracker system have been evaluated in field tests against TOW missiles at Redstone Arsenal, Alabama where designation and tracking functions were demonstrated at a range of 850 meters using a low energy (5 millijoule) laboratory laser. Additionally, laser attenuation in the presence of rocket motor plume effects has been evaluated during rocket motor static firing, and attenuation values of less than 50 percent (maximum, worst case relational geometry) were demonstrated.

Figures 5 through 8 show predicted clear weather performance of the threat warning, tracking, and designating systems against a large subset if the surrogate threat list. Performance of both WFOV MWIR and WFOV LWIR threat warning sensors against 81mm mortars is currently under evaluation.

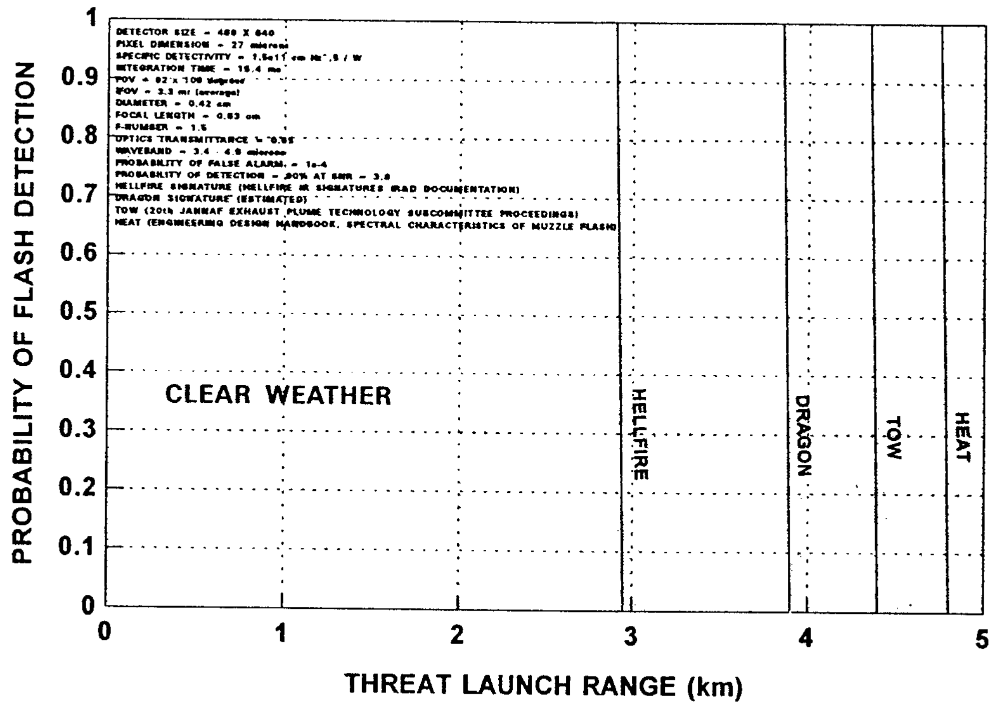

Figure 5. Threat Warning Sensor Performance against Threat Launch Flashes

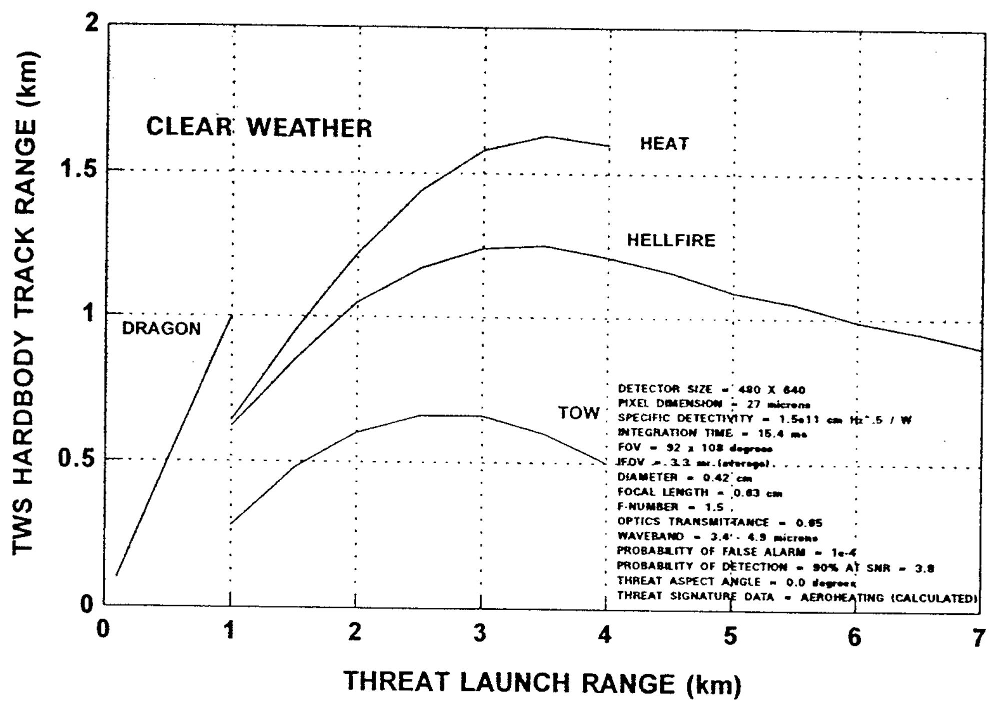

Figure 6. Threat Warning Sensor Performance against Threat Airframe with Aerodynamic Heating

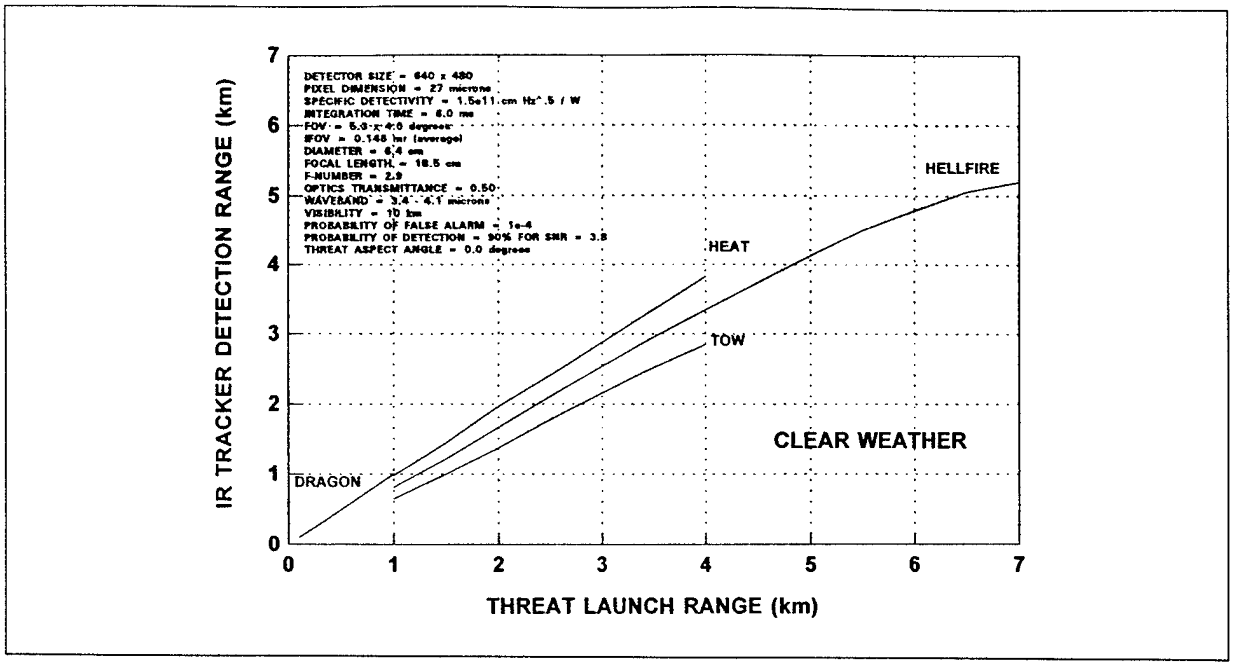

Figure 7. Tracking Sensor Performance against Threats

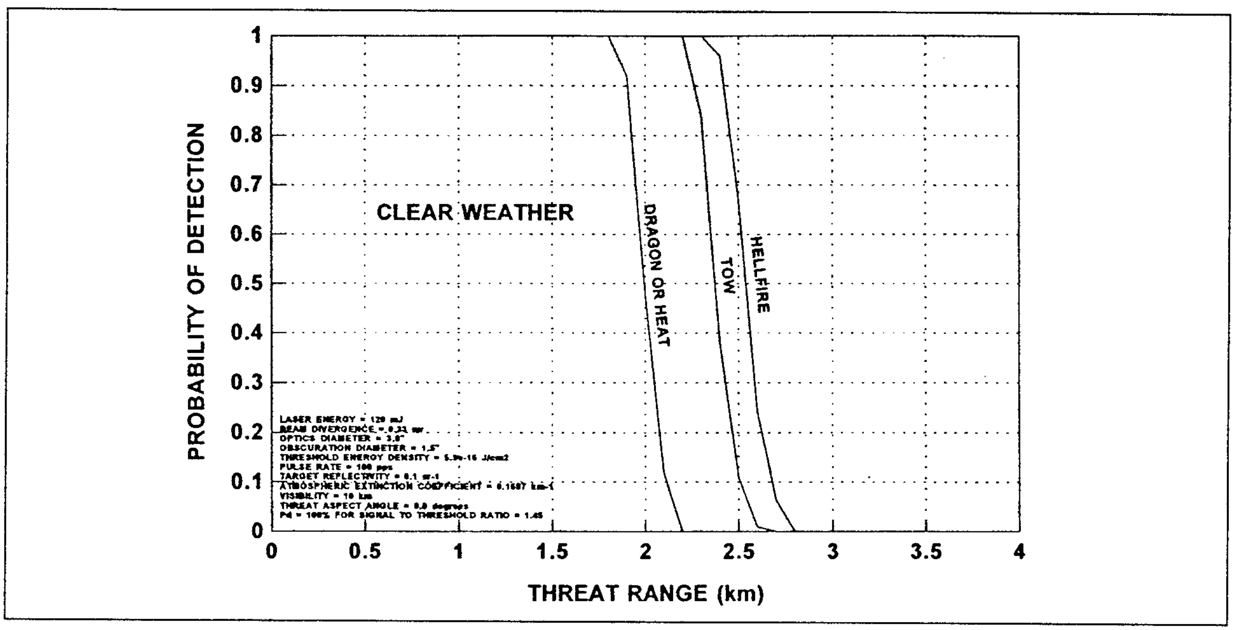

Figure 8. Laser Rangefinder/Designator Performance against Threats

Conclusions

Almost all of the SLID FCS technologies have been demonstrated in real-time field evaluations against a large subset of the surrogate threats, and prototype hardware is currently being designed and fabricated for end-to-end field tests against live targets in mid 1998. Test objectives include intercepts of TOW and mortar threats at ranges in excess of 100 meters, and the successful conclusion of this test series will signal readiness for full scale development, production, and fielding of SLID systems for protection of allied troops and assets on future battlefields.

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